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RCRA Facility Investigation

Preliminary Summary: Phase I Facility Investigation

Notes on Phase II Proposal

CIBA-GEIGY Facility

Cranston, Rhode Island

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June 1991

PRELIMINARY SUMMARY:
PHASE I FACILITY INVESTIGATION

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This document summarizes preliminary results from Phase I of the RCRA Facility Investigation (RFI) of the CIBA-GEIGY facility at Cranston, Rhode Island.

OVERVIEW

The work plan for Phase I of the Facility Investigation, approved on 11 July 1990, involved three main studies — a *physical characterization*, a *release characterization*, and an *off-site investigation*. The physical characterization was designed to determine the environmental setting of the facility and involved four interrelated investigations — geophysical, geological, hydrogeological, and hydrological. The release characterization was designed to determine the impact of releases at the site and was organized geographically based on the three study areas at the site (the Production, Waste Water Treatment, and Warwick areas) and the Pawtuxet River. Figure ES-1 shows the locations of the solid waste management units (SWMUs), areas of concern (AOCs), and additional areas of investigation (AAOIs) examined in each study area. For the river, three reaches were examined: the upstream reach, the facility reach (bordered by the site), and the downstream reach of the river. The off-site investigation was designed to characterize the conditions surrounding the site.

A PRELIMINARY SITE MODEL

The results from the Phase I physical characterization were synthesized into a preliminary Site Model. This physical conceptual model presents the geological *framework* of the site (based on the results from the Phase I geophysical and geological investigations) and the hydrologeological and hydrological *dynamics* at the site (based on the results from the Phase I hydrogeological and hydrological investigations). Finally, the implications of the Site Model for Phase II of the Facility Investigation are discussed.

Framework of the Site

The geophysical and geological investigations provided a preliminary understanding of the framework of the site. In general, the site is in the Narragansett Basin and is underlain by the Rhode Island

formation. Pleistocene glaciation scoured the bedrock surface and deposited till and outwash sediments as it receded. Two main rock types were found in nearby bedrock outcrops and in rock cores from the site — a medium-grained gray sandstone and a dark gray shale; both rock types underwent low-grade metamorphism.

Overall, five main geological units appear to underlie the site: 1) *Sand/Fill*, 2) *Silt*, 3) *Fine Sand*, 4) *Glacial Till*, and 5) *bedrock*. The Silt underlies the Warwick and Waste Water Treatment areas, but seems to pinch out in the eastern portion of the Production Area; a gravelly sand unit in the central portion of the Production Area may be a preferential pathway for groundwater. The stratigraphy seems to be fairly uniform in the Warwick and Waste Water Treatment areas; however, the Glacial Till does not underlie most of the Warwick Area and the Fine Sand appears to pinch out in the Waste Water Treatment Area.

Dynamics of the Site

The hydrogeological and hydrological investigations provided a preliminary understanding of the dynamics of water flow at the site. In general, the bedrock aquifer seems to be confined, and groundwater appears to flow through that aquifer in a south-southwesterly direction. The overburden aquifer seems to range from being unconfined to semi-confined. In the overburden aquifer, groundwater flow is controlled by both site stratigraphy and artificial structures, and generally flows toward and discharges to the river (about 395 ft^3/day from the Production Area). As much as 70% of the discharge may occur through 20% of the cross-sectional area in the Production Area, and the groundwater velocity may range from 0.5 to 65 ft/year.

The overburden aquifer generally has upward vertical gradients except at the bulkhead, where groundwater flows downward (under the bulkhead) and discharges to the river (possibly being forced toward the south riverbank). The deep and shallow portions of the overburden aquifer seem to have similar patterns of equipotentials and flow directions. High bedrock elevations create steep gradients in the Waste Water Treatment Area and in the adjacent off-site area; topography creates steep gradients in the northern portion of the Waste Water Treatment Area. The aquifer recharges rapidly after rainfall, and 25% of rainfall may go to the recharge.

Groundwater elevations are higher than the river water level elevations, verifying that the Pawtuxet River is a gaining stream. The shapes of the facility and the USGS rating curves are similar. The discharge values in the river correspond to the 30th through 70th percentiles of the USGS discharge frequency statistic at the Cranston gauge, but groundwater discharge along the facility reach cannot be measured using stream discharge monitoring. Suspended sediment concentrations were low during the

three time periods monitored, and suspended sediment discharge increases with increased water discharge. Bed sediment ranges from silt to gravel. Sediment transport rates probably are low under the flow rates observed; likely, only silt can be mobilized under low to moderate flow conditions.

Implications of the Site Model

The preliminary Site Model suggests the following implications for Phase II:

The Production Area stratigraphy is highly variable. The stratigraphy of the Production Area contains various lenses and minor units, and units pinch out at places. Because a gravelly sand unit in the central portion of the Production Area may be a preferential pathway for groundwater, understanding the extent of the gravel unit in the Production Area is critical. In Phase II, the stratigraphy of the Production Area will be characterized in greater detail by advancing additional continuous-sample borings where needed. Downhole geophysical logging of selected wells will be performed to produce detailed lithological trends of laterally continuous units.

Characterizing the overburden aquifer is crucial. Groundwater flow in the overburden aquifer is intricate, but clearly discharges to the river. The groundwater divide created by the bulkhead further complicates the flows. In Phase II, the hydrogeological conditions in the overburden aquifer will be characterized more completely by installing additional shallow and deep monitoring wells to provide information about horizontal and vertical flow patterns. Additional hydrogeological testing, including long-term pump testing (if permitted), will provide information about parameters of the aquifer and allow evaluation of the impact of the bulkhead on groundwater and surface water interactions.

Linking the hydraulics of the overburden aquifer and the river is important. Discharges from the overburden aquifer to the river will be understood better in order to model groundwater flow and contaminant transport. In Phase II, the link between the aquifer and river hydraulics will be characterized further by installing in the river (if permitted) clustered monitoring wells and piezometers that will penetrate the overburden aquifer. In addition, installing a continuous water level recorder in a stilling well in the river (if permitted) will allow comparing the river stage and groundwater elevations.

Linking the site and regional hydrogeology is important. Similarly, how the groundwater at the site interacts with groundwater off-site will be understood in order to model groundwater flow and contaminant transport. In Phase II, water level data will be collected at off-site locations to characterize the link between the site and regional hydrogeology.

Sediment grain size is highly variable. Variability in the riverbed may be associated with variable contamination in the riverbed sediment. Directly investigating the riverbed by videotaping, and additional sediment sampling, will be done in Phase II to characterize the variability of the riverbed in greater detail.

THE PHASE I RELEASE CHARACTERIZATION

This section summarizes the preliminary results of the Phase I release characterization. Two rounds of sampling were conducted in the Phase I release characterization; *this summary reflects the results from only the first sampling round.*

The Production Area Release Characterization

The release characterization of the Production Area evaluated the impacts of known or suspected releases where most of the chemical manufacturing operations occurred at the facility.

Locations Evaluated in the Production Area

The release characterization evaluated seven locations in the Production Area:

SWMU-2 — 6000-Gallon Hazardous Waste Storage Tank. Soil and groundwater were analyzed for Appendix IX compounds, fingerprint compounds, major ions, and treatability parameters.

SWMU-3 — 7500-Gallon, 90-Day Storage Tank. Soil and groundwater were analyzed for Appendix IX compounds, fingerprint compounds, major ions, and treatability parameters.

SWMU-7 — Chlorosulfonic Acid Release Area. Soil and groundwater were analyzed for Appendix IX compounds, fingerprint compounds, major ions, and treatability parameters.

SWMU-8 — Prussian Blue Release Area. Soil and groundwater were analyzed for Appendix IX compounds, fingerprint compounds, major ions, and treatability parameters.

SWMU-11 — Toluene Release Area. Soil and groundwater were analyzed for Appendix IX compounds, fingerprint compounds, major ions, and treatability parameters.

AOC-13 — Process Building Area. Soil and groundwater were analyzed for Appendix IX compounds, fingerprint compounds, major ions, and treatability parameters.

AAOI-15 — Laboratory Building Waste Water Sump. Soil and groundwater were analyzed for Appendix IX compounds, fingerprint compounds, major ions, and treatability parameters.

Table ES-1 summarizes the Media of Concern sampled, the number of samples collected, and the analyses conducted on samples from each of these locations. All of the compounds detected that were not attributable to blank contamination are discussed. Metals occur naturally in both soil and water, and were detected in all of the samples analyzed. For soil samples, several references were used to establish "baseline" concentrations of metals in U.S. soils; for water samples, current maximum contaminant levels (MCLs) and secondary drinking water standards were used to determine baseline metal concentrations. This document reports metal concentrations only for those samples having metals in concentrations exceeding these baseline criteria.

Results of the Production Area Release Characterization

The release characterization provided the following information about the SWMUs, AOCs, and AAOIs in the Production Area:

Soil — Organic Analytes. Surficial soil samples had total concentrations of volatile organic compounds (VOCs) of less than 1 ppm; soil samples from borings (deeper) had higher VOC concentrations (except for SWMU-2). The highest detections of VOCs were in samples from borings in SWMU-8 (mostly xylenes) and SWMU-11 (mostly toluene). Overall, the list of VOCs detected is limited; ethylbenzene, methylene chloride, toluene, and xylenes were detected most frequently. Nearly all the samples contained semi-volatile organic compounds. Polycyclic aromatic hydrocarbons (PAHs) generally were detected in a wider variety and in higher concentrations in the surficial soil samples than in the deeper samples; surficial samples with the highest levels were from the western edge of the Production Area. Two fingerprint compounds were detected: Irgasan DP-300 was detected in two samples from borings and Tinuvin 327 was detected in two other samples. PCBs were detected in all but one of the surficial soil samples (ranging from 1.4 to 51 ppm) and were highest in the southern portion of the main Production Area; lower PCB concentrations (0.85 to 13 ppm) were detected in the samples from borings. Furans were detected in nearly all the samples (usually less than 1 ppm); the samples from borings in SWMU-11 contained 35 and 150 ppm of tetrachlorodibenzofuran.

Soil — Inorganic Analytes. One sample from a boring contained an elevated level of lead (339 ppm); about half the surficial samples contained elevated levels of lead and mercury, and two surficial samples contained an elevated level of zinc. Cyanide was detected (1.2 and 1.7 ppm) in two samples from borings at SWMU-8 and in about half the surficial samples (ranging from 0.78 to 12.6 ppm).

Groundwater — Organic Analytes. Few organic compounds were detected in the samples from SWMU-2 and AAOI-15 — VOCs ranged up to 11 ppb, and the total concentration of semi-volatile organic compounds ranged up to 4 ppb. Pesticides were detected in concentrations similar to those found off-site (discussed later). Few organic compounds were detected in the sample from the bedrock well; more organic compounds were detected in the samples from the overburden wells. The overburden samples from SWMU-11 had the greatest number of organic compounds (mostly toluene); the samples from SWMU-7 had compounds similar to those in SWMU-11 (mostly xylenes). The samples from SWMUs-7 and -11 had chloro- and methyl-phenols up to 1000 ppb. The deep overburden samples from SWMU-7 had the same types (but lower concentrations) of compounds as the shallow overburden samples. The samples downgradient from SWMU-7 had types of compounds similar to those detected at SWMU-7, but sidegradient samples had fewer compounds. The shallow overburden samples near the river had chlorobenzene (up to 11,000 ppb) as well as several phenols (up to 277 ppb); few organic compounds were detected in the deep overburden sample near the river.

Groundwater — Inorganic Analytes. Nearly all the samples contained elevated levels of iron and manganese; a few samples contained elevated levels of chromium, arsenic, lead, and mercury.

Impact of the Production Area Release Characterization

The release characterization of the Production Area revealed no data gaps for SWMU-2 (the 6000-Gallon Hazardous Waste Storage Tank) or AAOI-15 (the Laboratory Building Waste Water Sump), but did reveal data gaps for other locations that will be addressed in Phase II:

SWMU-3 — 7500-Gallon, 90-Day Storage Tank. In soil, the xylenes detected in samples from borings will be delineated; the chemistry of groundwater downgradient from SWMU-3 will be evaluated. Additional soil borings will be advanced and sampled; additional downgradient wells will be installed and sampled.

SWMU-7 — Chlorosulfonic Acid Release Area. In soil, the toluene and PCBs detected in samples from borings will be delineated; the chemistry of groundwater downgradient from SWMU-7 will be evaluated. Additional soil borings will be advanced and sampled; additional downgradient wells will be installed and sampled.

SWMU-8 — Prussian Blue Release Area. In soil, the ethylbenzene and xylenes detected in samples from borings will be delineated; the vertical extent of groundwater contamination both

at, and downgradient from, SWMU-8 will be delineated. Additional soil borings will be advanced and sampled; additional wells will be installed and sampled.

SWMU-11 — Toluene Release Area. In soil, the toluene detected in samples from borings will be delineated; the horizontal and vertical extent of groundwater contamination both at, and downgradient from, SWMU-11 will be delineated. Additional soil borings will be advanced and sampled; additional wells will be installed and sampled.

AOC-13 — Process Building Area. In soil, the PCBs detected in samples will be delineated both horizontally and vertically; the boundaries of groundwater contamination will be delineated both sidegradient and upgradient for the entire main Production Area. The background chemistry of groundwater entering AOC-13 from the north (upgradient) will be evaluated by installing and sampling an upgradient monitoring well. The impact that groundwater discharging from AOC-13 has on the river, and on the overburden aquifer beneath the river, will be evaluated by sampling the in-river monitoring wells (if permitted).

The Waste Water Treatment Area Release Characterization

The release characterization of the Waste Water Treatment Area evaluated the impacts of known or suspected releases where the facility's waste water treatment plant operated.

Locations Evaluated in the Waste Water Treatment Area

In the Waste Water Treatment Area, the release characterization evaluated two locations:

SWMU-10 — Waste Water Pipeline Break - Waste Water Treatment Area. Soil and groundwater, as well as surface water and sediment in the pond near SWMU-10, were analyzed for Appendix IX compounds, fingerprint compounds, major ions, and treatability parameters.

SWMU-12 — Waste Water Treatment Plant. Soil and groundwater were analyzed for Appendix IX compounds, fingerprint compounds, major ions, and treatability parameters.

Table ES-1 summarizes the Media of Concern sampled, the number of samples collected, and the analyses conducted on samples from each of these locations.

Results of the Waste Water Treatment Area Release Characterization

The release characterization provided the following information about the SWMUs in the Waste Water Treatment Area:

Soil — Organic Analytes. The samples from SWMU-10 had total concentrations of volatile and semi-volatile organic compounds less than 1 ppm. The samples from SWMU-12 had VOCs up to 6.5 ppm (mostly ethylbenzene, methylene chloride, toluene, and xylenes) and semi-volatile organic compounds up to 21.11 ppm (mostly PAHs). One sample contained several fingerprint compounds (394 ppm), phenols (5.7 ppm), and furans (128.4 ppm). Furans were detected in the other samples at lower concentrations. All the samples contained pesticides (up to 4.13 ppm) and one sample contained the herbicide 2,3,5-T (at 0.046 ppm).

Soil — Inorganic Analytes. All the samples from SWMU-10 contained elevated levels of metals at low concentrations; in SWMU-12, two samples contained an elevated level of lead and one sample contained an elevated level of zinc. No cyanide was detected in these samples.

Groundwater — Organic Analytes. Few organic compounds were detected in the samples from the upgradient and downgradient overburden wells and in the sample from the bedrock well — the total concentration of VOCs ranged up to 5.5 ppb, and the total concentration of semi- volatile organic compounds ranged up to 42 ppb. Pesticides were detected in concentrations similar to those found off-site. The sample from the shallow well in the center of the Waste Water Treatment Area contained more organic compounds (including many of the compounds detected in the Production Area) — the total concentration of VOCs was 84.3 ppb, and the total concentration of semi-volatile organic compounds was 840 ppb (for fingerprint compounds) and 206 ppb (for non-fingerprint compounds). The sample also contained 1.01 ppb of pesticides.

Groundwater — Inorganic Analytes. Nearly all the samples contained elevated levels of iron and manganese.

Surface Water — Organic Analytes. Two pesticides were detected in the sample: aldrin (at 0.016 ppb) and 4,4' DDE (at 0.012 ppb).

Surface Water — Inorganic Analytes. The sample contained an elevated level of iron (1810 ppb).

Sediment — Organic Analytes. No VOCs were detected in either sample; total concentrations of semi-volatile organic compounds in the two samples were 5.14 and 12.6 ppm (mostly PAHs,

and tetra- and dichlorobenzofuran). Trichlorodibenzofuran was detected in both samples at 0.0034 and 0.010 ppm. One sample contained the pesticide 4,4' DDD at 0.014 ppm.

Sediment — Inorganic Analytes. Calcium (1550 ppm), vanadium (11.9 ppm), and zinc (161 ppm) were detected at levels significantly above those in the sediment sample from the upstream reach of the Pawtuxet River (discussed later).

Impact of the Waste Water Treatment Area Release Characterization

The release characterization of the Waste Water Treatment Area revealed no data gaps for SWMU-10 (the Waste Water Pipeline Break in the Waste Water Treatment Area), but did reveal data gaps at SWMU-12 that will be addressed in Phase II:

SWMU-12 — Waste Water Treatment Plant. The vertical and horizontal extent of soil contamination will be delineated; the extent of groundwater contamination downgradient from SWMU-12 will be delineated for the analytes detected in samples from MW-15S. Additional soil borings will be advanced and sampled; an additional well downgradient from SWMU-12 will be installed and sampled.

The Warwick Area Release Characterization

The release characterization of the Warwick Area evaluated the impacts of known or suspected releases in the portion of the facility south of the Pawtuxet River.

Locations Evaluated in the Warwick Area

In the Warwick Area, the release characterization evaluated four locations:

SWMU-5 — River Sediment Storage Area. Soil and groundwater were analyzed for Appendix IX compounds, fingerprint compounds, major ions, and treatability parameters.

SWMU-6 — Zinc Oxide/Soil Pile. Soil was analyzed for Appendix IX compounds, fingerprint compounds, major ions, and treatability parameters.

SWMU-9 — Waste Water Pipeline Break - Warwick Area. Soil was analyzed for Appendix IX compounds, fingerprint compounds, major ions, and treatability parameters.

AAOI-16 — Maintenance Department Cleaning Area. Soil and groundwater were analyzed for Appendix IX compounds, fingerprint compounds, major ions, and treatability parameters.

Table ES-1 summarizes the Media of Concern sampled, the number of samples collected, and the analyses conducted on samples from each of these locations.

Results of the Warwick Area Release Characterization

The release characterization provided the following information about the SWMUs and AAOIs in the Warwick Area:

Soil — Organic Analytes. The surficial samples from SWMUs-6 and -9 mostly contained pesticides (up to 0.283 ppm); no organic compounds were detected in the sample from AAOI-16. The samples from SWMU-5 had VOCs up to about 5 ppm (mostly chlorobenzene, tetrachloroethylene, toluene, and xylenes), semi-volatile organic compounds up to 128 ppm (mostly PAHs and phthalates), and pesticides ranging from 3.64 to 8.218 ppm (except one sample had 2200 ppm of methoxychlor). Two samples contained the herbicide 2,4,5-TP (Silvex) at 0.11 and 0.21 ppm.

Soil — Inorganic Analytes. Two samples from SWMU-9 contained an elevated level of lead; the sample from SWMU-6 contained an elevated level of zinc; samples from SWMU-5 contained elevated levels of chromium, copper, lead, and zinc. Cyanide was detected in all the samples from SWMU-5 (up to 9.4 ppm) and in the sample from SWMU-6 (at 0.99 ppm).

Groundwater — Organic Analytes. Few organic compounds were detected in the samples from the shallow overburden well and the bedrock well in SWMU-5, except the shallow overburden sample contained Propazine (a fingerprint compound) at 35 ppb. The sample from the well downgradient from SWMU-5 contained several organic compounds similar to those detected in the wells along the river in the Production Area (mostly chlorobenzene at 3500 ppb); the levels of pesticides detected in this sample were similar to those detected in samples from wells off-site.

Groundwater — Inorganic Analytes. Nearly all the samples contained elevated levels of iron and manganese.

Impact of the Warwick Area Release Characterization

The release characterization of the Warwick Area revealed no data gaps for SWMU-6 (the Zinc Oxide/Soil Pile) or SWMU-9 (the Waste Water Pipeline Break in the Warwick Area), but did reveal data gaps for other locations that will be addressed in Phase II:

SWMU-5 — River Sediment Storage Area. The vertical and horizontal extent of soil contamination will be delineated; the horizontal extent of groundwater contamination downgradient from SWMU-5, and the vertical extent of groundwater contamination in the overburden aquifer, will be delineated for the compounds detected in the samples from MW-11S. Additional soil borings will be advanced and sampled; an additional well downgradient from SWMU-5 will be installed and sampled.

AAOI-16 — Maintenance Department Cleaning Area. No analytes were detected in the soil at AAOI-16, so the source of analytes detected in the groundwater at AAOI-16 will be identified; the extent of groundwater contamination downgradient from AAOI-16, and the vertical extent of groundwater contamination in the shallow portion of the overburden aquifer, will be delineated.

The Pawtuxet River Release Characterization

The release characterization of the Pawtuxet River evaluated the impacts of known or suspected releases on the river water and riverbed.

Locations Evaluated in the Pawtuxet River

The release characterization evaluated three reaches of the Pawtuxet River:

Upstream reach. Two surface water and two riverbed sediment samples were collected from the reach extending about 0.4 miles upstream of the facility, and were analyzed for Appendix IX compounds, fingerprint compounds, major ions, and treatability parameters.

Facility reach. Five surface water and nine sediment samples (including duplicates) were collected from the reach of the river bordered by the facility, and were analyzed for Appendix IX compounds, fingerprint compounds, major ions, and treatability parameters.

Downstream reach. Three surface water and three sediment samples were collected from the reach extending about 0.4 miles downstream of the facility, and were analyzed for Appendix IX compounds, fingerprint compounds, major ions, and treatability parameters.

Bioassay analyses also were conducted on samples of water and sediment — the toxicity of surface water was assessed using *Pimephales promelas* (a minnow) and *Ceriodaphnia dubia* (a small invertebrate); the toxicity of sediment pore waters was assessed using *C. dubia*; the toxicity of the sediment itself was assessed using the larvae of *Chironomus tentans* (a small insect). Survival rates were measured for all three organisms; reproduction rates were measured for *C. dubia*. Table ES-1 summarizes the Media of Concern, number of samples, and chemical analyses conducted on samples

from these reaches. For inorganic analyses of sediments, the levels of analytes detected in sample SD-00M (the far upstream sample) were used as the baseline.

Results of the Pawtuxet River Release Characterization

The release characterization provided the following information about the three reaches of the river:

Surface Water — Organic Analytes. The chemistry of surface water samples from all three reaches was similar. Low levels of VOCs, phthalates, and pesticides were present in samples from all the reaches.

Surface Water — Inorganic Analytes. Lead, nickel, and zinc were detected in all three reaches. Silver was found only in the facility reach, and cyanide was present only in the downstream reach.

Surface Water — Bioassay. The survival rates of *P. promelus* and *C. dubia* in surface water samples from all three reaches did not differ significantly from the laboratory control. However, the reproduction rates of *C. dubia* were significantly lower than the laboratory control in some upstream and downstream reach samples.

Sediment — Organic Analytes. Several types of contaminants were detected in sediment samples. The far upstream sediment sample contained relatively low levels of PAHs. The near upstream sample contained VOCs, phthalates, PAHs, chlorinated benzenes, and dioxins/furans. The facility reach sediment samples contained the same types of compounds observed in the near upstream sample, as well as phenols, fingerprint compounds, PCBs, pesticides, and herbicides. Sediment samples from the downstream reach had fewer types of contaminants than facility reach samples; phthalates, PAHs, fingerprint compounds, and pesticides were detected. In general, the facility reach samples had higher concentrations of organic compounds than the upstream or downstream reach samples.

Sediment — Inorganic Analytes. The following Appendix IX metals were detected in sediment samples: beryllium, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium, silver, thallium, tin, vanadium, and zinc. The facility reach sediment samples had higher concentrations of metals than samples from the upstream or downstream reaches.

Sediment — Bioassay. The survival rates of *C. tentans* larvae in sediment from the upstream reach did not differ significantly from the survival rates of larvae in control sediment. The

survival rate in sediment from four facility reach samples was zero; the survival rates in sediment from the other two facility reach samples were significantly lower than in the control sediment and upstream samples. However, the survival rate in control sediment (60%) was lower than is usually considered minimal (80%) for control samples. The survival rate in the near downstream sample did not differ significantly from control conditions; however, the survival rate in the far downstream sample was significantly lower than in the control sediment and upstream samples. The survival rates of *C. dubia* in pore waters from 1) both upstream samples, 2) four of the six facility reach samples, and 3) all the downstream samples did not differ significantly from control conditions. The survival rates in sediment pore waters in the other two facility reach samples were significantly lower than for the control and upstream samples.

Impact of the Pawtuxet River Release Characterization

The release characterization of the Pawtuxet River revealed these data gaps to be addressed in Phase II:

Ensure generalizability of results. Because the Phase I sampling locations had been selected based on known or suspected releases, those locations were biased and the results obtained may not be generalizeable throughout the reaches of the river that were investigated. In Phase II, stratified random sampling of the river sediment will be performed to ensure that the release characterization results can be generalized along the river reaches.

Isolate grain size effects. Both coarse- and fine-grained samples will be collected at some riverbed locations to measure and isolate the effects of grain size on the release characterization results from Phase I.

Additional sediment testing. Additional testing of riverbed sediments will be conducted as needed to evaluate options for corrective measures.

Vertical variation. The vertical distribution of analytes and other parameters will be determined in both surface water and sediment samples.

Horizontal variation. The horizontal distribution of analytes and other parameters will be determined in sediment samples.

Temporal changes. The variation of surface water chemistry with respect to time will be measured by collecting surface water samples from one facility reach location on several different dates.

THE OFF-SITE INVESTIGATION

This section summarizes the preliminary results of the Phase I off-site investigation.

Locations Evaluated in the Off-Site Investigation

The off-site investigation evaluated seven off-site locations. Surficial soil from four background locations (Pilgrim High School, New Dutemple School, Wyman School, and Belmont Park) and groundwater from three upgradient locations (MW-18S, MW-19S, and RW-4) were sampled. All surficial soil and groundwater samples were analyzed for Appendix IX compounds and fingerprint compounds. Table ES-1 summarizes the Media of Concern, number of samples, and analyses conducted on samples from these locations.

Results of the Off-Site Investigation

The off-site investigation provided the following information:

Soil — Organic Analytes. Only low levels (less than 1.5 ppm) of VOCs were detected in the off-site soil samples. All four samples contained bis(2ethylhexyl)phthalate (0.18 to 2.3 ppm), PAHs (0.248 to 92.13 ppm), and pesticides (0.005 to 0.060 ppm). No PCBs, no dioxins or furans, and no herbicides were detected in any of the off-site soil samples.

Soil — Inorganic Analytes. Two samples contained an elevated level of arsenic; two samples contained an elevated level of lead. No cyanide was detected in any of the off-site soil samples.

Groundwater — Organic Analytes. One shallow well sample contained diethylphthalate and napthalene (2 ppb); the other shallow well sample contained PAHs (7 ppb). Pesticides were detected in all three samples (0.0171 to 0.121 ppb). No VOCs, PCBs, dioxins or furans, or herbicides were detected in the groundwater samples from the off-site monitoring wells.

Groundwater — Inorganic Analytes. Both shallow well samples contained elevated levels of arsenic, chromium, and iron; the deep well sample also contained an elevated level of iron. All three samples contained elevated levels of manganese. No cyanide was detected in any of the groundwater samples from the off-site wells.

Impact of the Off-Site Investigation

The off-site investigation revealed data gaps that will be addressed in Phase II:

Soil. Background soil will not be sampled again unless required for Risk Assessment purposes. However, the fourteen other off-site locations sampled in Round 2 of Phase I (not discussed in this document) will be resampled in Phase II to confirm the results.

Groundwater. Water chemistry data will be obtained for upgradient groundwater entering the Warwick Area from the south.

SELECTION OF TARGET COMPOUNDS

The analytical results were summarized for both the on-site and off-site areas. Because only the first round of sampling results was available, the list of all the compounds detected was taken to constitute the preliminary list of target chemicals. This list has been summarized by SWMU, location, and Medium of Concern. Of the roughly 230 individual compounds or groups of compounds either listed in Appendix IX or included as fingerprint compounds, about 100 had been detected in surficial soil or groundwater samples collected on-site; five more compounds were detected in the sediment samples from the Pawtuxet River. The highest concentrations of Appendix IX compounds in surficial soil and groundwater samples were detected in the Production Area. Riverbed sediment samples collected near the Production Area had the highest concentrations of Appendix IX compounds and fingerprint compounds detected off-site.

CONCLUSIONS

As a result of Phase I of the Facility Investigation, pursuant to the Order:

- no additional Media of Concern were identified;
- no additional solid waste management units, areas of concern, or additional areas of investigation were identified; and
- no interim measures are recommended at the site.

However, the Phase I results suggest the following implications for Phase II:

Some additional physical characterization of the site will be done. The stratigraphy of the Production Area will be characterized further by advancing additional continuous-sample borings; downhole geophysical logging of selected wells will produce detailed lithological trends of laterally continuous units. The hydrogeological conditions in the overburden aquifer will be characterized more completely by installing additional shallow and deep monitoring wells; additional hydrogeological testing will provide information about parameters of the aquifer and allow evaluation of the impact of the bulkhead on groundwater and surface water interactions. The link between the aquifer and river hydraulics will be characterized by installing clustered monitoring wells and piezometers in the river (if permitted); installing a continuous water level recorder in a stilling well in the river will permit comparing the river stage and groundwater elevations. Water level data will be collected off-site to characterize the link between the site and regional hydrogeology. Finally, the riverbed will be investigated directly by videotaping, and additional sediment sampling will characterize the variability of the riverbed in greater detail.

Additional release characterization of the Production Area will be done. In SWMU-3, the xylenes detected in soil samples will be delineated and the downgradient groundwater will be evaluated. In SWMU-7, the toluene and PCBs detected in soil samples will be delineated and the downgradient groundwater will be evaluated. In SWMU-8, the ethylbenzene and xylenes will be delineated and the groundwater contamination at, and downgradient from, SWMU-8 will be delineated. In SWMU-11, the toluene detected in soil samples will be delineated and the groundwater contamination at, and downgradient from, SWMU-11 will be delineated. In AOC-13, the PCBs detected in soil samples will be delineated and the groundwater contamination will be delineated both sidegradient and upgradient for the entire main Production Area. The background chemistry of upgradient groundwater entering AOC-13 will be evaluated; the impact of groundwater discharges on the river, and on the aquifer beneath the river, will be evaluated using in-river monitoring wells (if permitted).

Additional release characterization of the Waste Water Treatment Area will be done. In SWMU-12, the extent of soil contamination will be delineated; the extent of downgradient groundwater contamination will be delineated for the analytes detected in samples from MW-15S.

Additional release characterization of the Warwick Area will be done. In SWMU-5, the extent of soil contamination will be delineated; the extent of groundwater contamination, both in the overburden aquifer and downgradient, will be delineated for the compounds detected in the samples from MW-11S. In AAOI-16, the extent of groundwater contamination, both in the shallow overburden aquifer and downgradient, will be delineated.

TABLE ES-1

PHASE 1 RELEASE CHARACTERIZATION SAMPLING SUMMARY
CIBA-GEIGY
CRANSTON, RHODE ISLAND

	MEDIA				PARAMETERS			
UNIT	SOIL	GROUND WATER	SURFACE WATER	SEDIMENT	APPENDIX IX	FINGERPRINT COMPOUNDS	MAJOR IONS	TREATABILITY
SWMU1	NR	NR	NR	NR	⊞	⊞	⊞	⊞
SWMU2	2/3	2/2	NR	NR	■	■	■	■
SWMU3[1]	2/3	2/2	NR	NR	■	■	■	■
SWMU4	NR	NR	NR	NR	⊞	⊞	⊞	⊞
SWMU5	5/8	3/3	NR	NR	■	■	■	■
SWMU6	1/3	NR	NR	NR	◪	◪	◪	◪
SWMU8	2/2	2/2	NR	NR	■	■	■	■
SWMU9	3/3	NR	*	*	◪	◪	◪	◪
SWMU10[2]	3/3	1/1	1/1	2/2	■	■	■	■
SWMU11	2/2	2/2	NR	NR	■	■	■	■
SWMU12	4/4	5/5	*	*	■	■	■	■
AOC13[3]	10/10	12/12	NR	NR	■	■	■	■
AOC14	NR	NR	NR	NR	⊞	⊞	⊞	⊞
AAOI15	1/2	2/2	NR	NR	■	■	■	■
AAOI16	1/2	2/2	NR	NR	■	■	■	■
OFF-SITE	0/14	NR	NR	NR	■	⊞	⊞	⊞
BACKGROUND OFF-SITE	4/4	3/3	NR	NR	■	■	⊞	⊞
RIVER	NR	NR	9/5	12/14	■	■	■	■

NOTES:

(1). GROUNDWATER SAMPLES ARE COMMON TO SWMUS-3 AND -7

(2). SURFACE WATER AND SEDIMENT SAMPLES WERE COLLECTED FROM THE POND LOCATED IN THE WASTE WATER TREATMENT AREA.

(3). SAMPLES ARE COMMON TO SWMU2, SWMU3, SWMU7, SWMU8, AND SWMU11.

TBD - BACKGROUND SAMPLING LOCATIONS FOR SURFACE WATER, SEDIMENT, AND GROUND WATER WILL BE DETERMINED IN CONSULTATION WITH EPA

LEGEND:

SOIL ⊞ GROUND WATER
SEDIMENT ■ SURFACE WATER

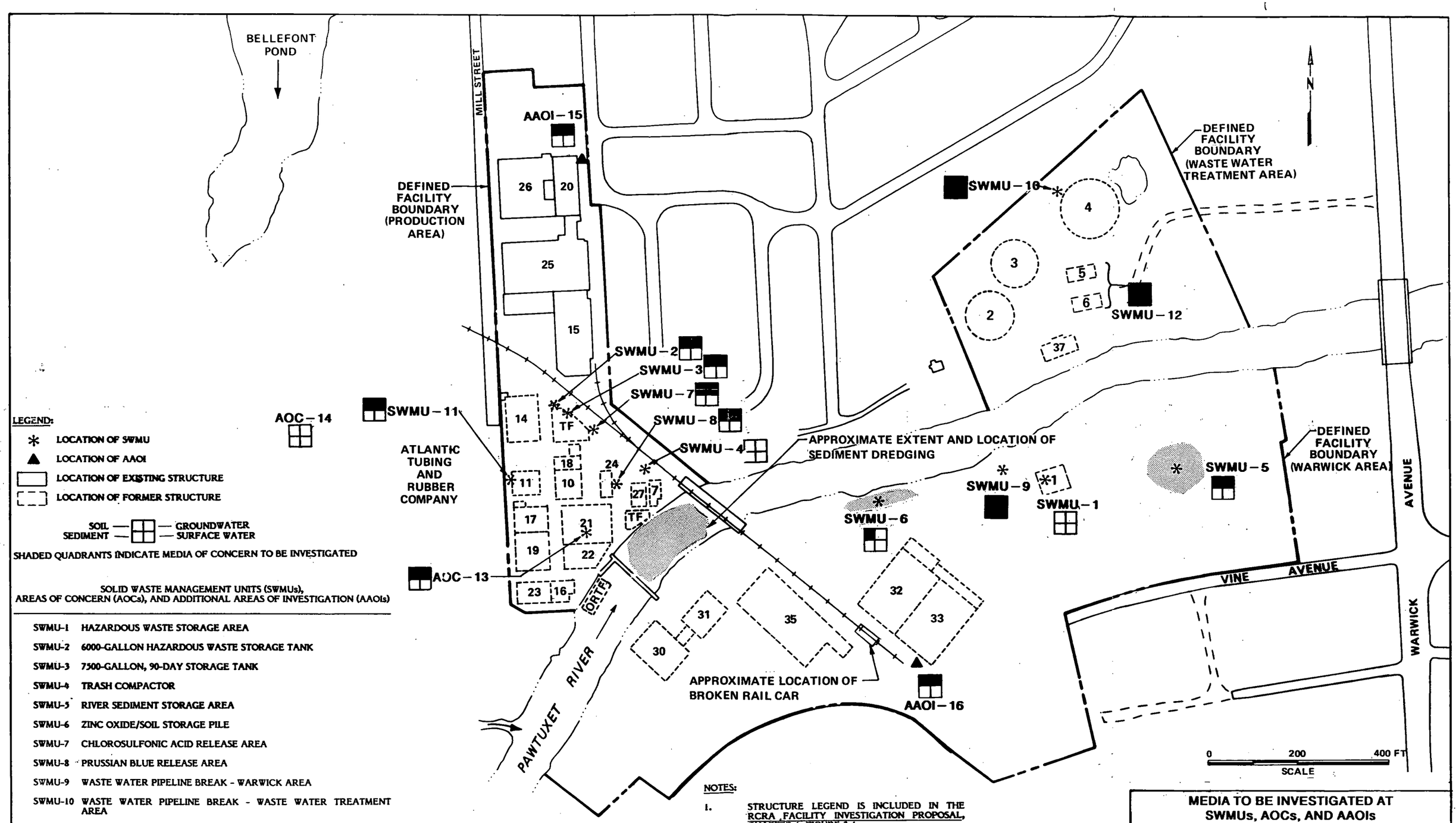
SHADED AREAS INDICATE MEDIA OF CONCERN INVESTIGATED

NR - NOT REQUIRED

* - ADDRESSED IN THE RIVER SECTION

1 - NUMBER OF SAMPLES COLLECTED IN ROUND 1

2 - NUMBER OF SAMPLES COLLECTED IN ROUND 2



LEGEND:

- * LOCATION OF SWMU
- ▲ LOCATION OF AAOI
- LOCATION OF EXISTING STRUCTURE
- LOCATION OF FORMER STRUCTURE

SOIL — — GROUNDWATER
SEDIMENT — — SURFACE WATER

SHADED QUADRANTS INDICATE MEDIA OF CONCERN TO BE INVESTIGATED

SOLID WASTE MANAGEMENT UNITS (SWMUs), AREAS OF CONCERN (AOCs), AND ADDITIONAL AREAS OF INVESTIGATION (AAOIs)

SWMU-1	HAZARDOUS WASTE STORAGE AREA
SWMU-2	6000-GALLON HAZARDOUS WASTE STORAGE TANK
SWMU-3	7500-GALLON, 90-DAY STORAGE TANK
SWMU-4	TRASH COMPACTOR
SWMU-5	RIVER SEDIMENT STORAGE AREA
SWMU-6	ZINC OXIDE/SOIL STORAGE PILE
SWMU-7	CHLOROSULFONIC ACID RELEASE AREA
SWMU-8	PRUSSIAN BLUE RELEASE AREA
SWMU-9	WASTE WATER PIPELINE BREAK - WARWICK AREA
SWMU-10	WASTE WATER PIPELINE BREAK - WASTE WATER TREATMENT AREA
SWMU-11	TOLUENE RELEASE AREA
SWMU-12	WASTE WATER TREATMENT PLANT
AOC-13	PROCESS BUILDING AREA
AOC-14	ATLANTIC TUBING AND RUBBER COMPANY PROPERTY
AAOI-15	LABORATORY BUILDING WASTE WATER SUMP
AAOI-16	MAINTENANCE DEPARTMENT CLEANING AREA

NOTES:

1. STRUCTURE LEGEND IS INCLUDED IN THE RCRA FACILITY INVESTIGATION PROPOSAL, CHAPTER 1, FIGURE 3-1.
2. CIBA-GEIGY HAS IDENTIFIED TWO ADDITIONAL AREAS OF INVESTIGATION (AAOIs). THOSE AAOIs HAVE BEEN DESIGNATED AS AAOI-15 AND AAOI-16.

BASE MAP SOURCE: GEOD CORPORATION OF NEWFOUNDLAND, NEW JERSEY, MAPPED BY PHOTOGRAMMETRIC METHODS FROM AERIAL PHOTOGRAPHS. DATE FLOWN: 2 APRIL 1989

MEDIA TO BE INVESTIGATED AT SWMUs, AOCs, AND AAOIs
CIBA – GEIGY FACILITY
CRANSTON, RHODE ISLAND

WOODWARD – CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
WAYNE, NEW JERSEY

DR. BY:	KF	SCALE:	1:2400	PROJ. NO.:	87X4660
CK'D. BY:	MH	DATE:	30 MAY 1991	FIG. NO.:	ES – 1

Additional release characterization of the Pawtuxet River will be done. Stratified random sampling of river sediment will ensure generalizeability. Both coarse- and fine-grained samples will be collected at some riverbed locations to isolate the effects of grain size. Additional sediment testing will provide information needed to evaluate options for corrective measures. The vertical distribution of analytes and other parameters will be measured in both surface water and sediment samples; the horizontal distributions will be measured in sediment samples. The temporal variation of surface water chemistry will be measured by collecting samples from one facility reach location on several dates.

Additional off-site investigation will be done. The fourteen other off-site locations sampled in Round 2 of Phase I will be resampled in Phase II to confirm the results, and upgradient groundwater entering the Warwick Area will be sampled to evaluate background chemistry.

NOTES ON
PHASE II PROPOSAL

NOTES ON PHASE II PROPOSAL

This document outlines a preliminary view of the work proposed for Phase II of the RCRA Facility Investigation of the CIBA-GEIGY facility at Cranston, Rhode Island. *It is based on the results from only the first round of sampling and analysis.*

Three Main Studies

The work plan for Phase II of the Facility Investigation involves three main studies — a *physical characterization*, a *release characterization*, and an *off-site investigation*. The *physical characterization* will fill data gaps about the environmental setting of the facility through four interrelated studies — geophysical, geological, hydrogeological, and hydrological investigations. The *release characterization* will fill data gaps about the impact of releases on the three study areas at the site (the Production, Waste Water Treatment, and Warwick areas), and on the Pawtuxet River. Finally, the *off-site investigation* will fill data gaps about the background conditions in the vicinity of the site.

Areas Investigated

The Production Area has six SWMUs (SWMU-2, SWMU-3, SWMU-4, SWMU-7, SWMU-8, and SWMU-11), two AOCs (AOC-13 and AOC-14), and one AAOI (AAOI-15). The Waste Water Treatment Area has two SWMUs (SWMU-10 and SWMU-12). The Warwick Area has four SWMUs (SWMU-1, SWMU-5, SWMU-6, SWMU-9) and one AAOI (AAOI-16). The Pawtuxet River has been divided into the upstream reach of the river, the facility reach of the river (bordered by the site), and the downstream reach. The off-site area has four background soil sampling locations, fourteen other soil sampling locations, and three upgradient groundwater sampling locations.

Organization of this Document

This document is organized in terms of the three main studies, the investigations or locations for each study, the data gaps identified in Phase I (or the data needs driving Phase II), the strategy for filling those data gaps or needs, and the tactical activities proposed to implement the strategy. Activities related to the Public Health and Environmental Risk Evaluation (PHERE) are summarized in Attachment A.

Phase II Physical Characterization

Geophysical Investigation

Summary of Phase I Results

- The seismic refraction and electrical resistivity surveys were useful for defining stratigraphy.
- The seismic refraction results agreed fairly well with the electrical resistivity results; the results from both surveys compared well with data from borings at the site.
- Three geological units appear to underlie the site:
  1) a layer of interbedded sands, gravels, silts, and clays about 20 to 50 feet thick;
  2) a glacial till of variable composition up to 30 feet thick;
  3) weathered, jointed, and/or saturated bedrock at about 45 to 60 feet deep.
- The water table varies from about 3 to 18 feet; no perched water tables were identified.

Phase I Data Gaps/Phase II Data Needs

- Extremes of bedrock depth in each study area may be artifactual and will be confirmed
- The stratigraphy will be better defined

Strategy for Phase II

- Confirm extremes of bedrock depth using a *seismic refraction survey*
- Confirm extremes of bedrock depth using an *electrical resistivity survey*
- Define overburden stratigraphy using *downhole geophysical logging*

Activities Proposed for Phase II

- Seismic refraction survey
  - — Production Area: 2 orthogonal survey lines to investigate bedrock depths
  - — Waste Water Treatment Area: 2 orthogonal survey lines to investigate bedrock depths
  - — Warwick Area: 2 orthogonal survey lines to investigate bedrock depths
- Electrical resistivity survey
  - — Production Area: 2 orthogonal survey lines to investigate bedrock depths
  - — Waste Water Treatment Area: 2 orthogonal survey lines to investigate bedrock depths
  - — Warwick Area: 2 orthogonal survey lines to investigate bedrock depths
- Downhole geophysical logging
  - — gamma logging
  - — deep monitoring wells
  - — selected shallow monitoring wells

Phase II Physical Characterization

Geological Investigation

Summary of Phase I Results

- The site is underlain by bedrock in the Rhode Island formation; glaciation scoured the bedrock and deposited till and outwash sediments.
- Outcrops correlated with rock cores from the site; two main rock types, a medium-grained gray sandstone and a dark gray shale, underwent low-grade metamorphism.
- The overburden deposits are highly varied (consistent with a glacial/fluvial, alluvial, and/or fluvial deposition); some stratigraphic units are vertically and horizontally discontinuous.
- Five main geological units were identified beneath the site:
  1) Sand/Fill (about 6 to 29 feet thick),
  2) Silt (about 6 to 38 feet thick),
  3) Fine Sand (about 5 to 37 feet thick),
  4) Glacial Till (about 5 to 10 feet thick), and
  5) bedrock (encountered at about 5 to 75 feet below mean sea level).
- The Silt seems to pinch out in the eastern Production Area; a gravel unit in the central Production Area may be a preferential pathway for groundwater.
- The stratigraphy is fairly uniform in the Warwick and Waste Water Treatment areas, but the Glacial Till does not underlie most of the Warwick Area and the Fine Sand seems to pinch out in the Waste Water Treatment Area.

Phase I Data Gaps/Phase II Data Needs

- The extent of the gravel unit in the central Production Area will be fully defined
- The stratigraphy in the Production Area will be fully defined

Strategy for Phase II

- *Investigate the gravel unit* to assess its importance as a preferential groundwater pathway
- *Investigate the stratigraphy of the Production Area where needed* to assess preferential groundwater pathways
- *Refine lithologic correlation with geophysical logs*

Activities Proposed for Phase II

- Investigate the gravel unit
  — advance soil borings in the central Production Area to define the extent of the unit
- Investigate the stratigraphy of the Production Area where needed
  — advance continuous-sample deep borings in the south and west Production Area
- Refine lithologic correlation with geophysical logs
  — produce detailed lithological trends and continuous units

Phase II Physical Characterization

Hydrogeological Investigation

Summary of Phase I Results

- The bedrock aquifer seems to be confined and groundwater appears to flow south-southwest; the overburden aquifer seems to range from being unconfined to semi-confined.
- Groundwater flows toward and discharges to the Pawtuxet River (about 395 ft^3/day from the Production Area) and is affected by the bulkhead; the hydraulic conductivity is variable, and 70% of the discharge to the river may occur through 20% of the cross-sectional area of the Production Area. Groundwater velocity may range from 0.5 to 65 ft/year.
- The overburden aquifer has upward vertical gradients except that groundwater flows under the bulkhead before discharging to the river. The deep and shallow portions of the overburden aquifer have similar patterns of equipotentials and flows.
- Bedrock elevations create steep gradients in the Waste Water Treatment Area and off-site next to the Production Area; topography creates steep gradients in the north Waste Water Treatment Area.
- Groundwater elevations are higher than river elevations. The aquifer recharges rapidly after rainfall, and 25% of the rainfall may contribute to the recharge.
- The hydrochemistry of groundwater is similar in both the shallow and deep portions of the overburden aquifer in the Production Area, indicating that the aquifer is unconfined; the hydrochemistry also confirms that the aquifer receives significant recharge from rainfall.

Phase I Data Gaps/Phase II Data Needs

- Interaction of the aquifers with the river will be characterized more completely
- Interaction of the site hydrogeology with the region's hydrogeology will be delineated
- Impact of the bulkhead on groundwater flow patterns will be fully defined

Strategy for Phase II

- *Monitor river stage elevations* to compare river levels with groundwater levels
- *Monitor water levels monthly* and install two new continuous recorders
- *Investigate the regional hydrogeology* and its link with the site hydrogeology
- *Investigate the impact of the bulkhead* on groundwater flow patterns
- *Correlate downhole geophysical logging* with hydraulic conductivity data
- *Conduct constant rate discharge pump tests* in two recovery wells

Activities Proposed for Phase II

- Monitor river stage elevations
  - — if permitted
  - — install a data logger in a stilling well in the river to monitor river stage continuously
  - — compare river elevations with groundwater elevations to link the site and river hydraulics

- Monitor water levels monthly
  - — and install two new continuous water level recorders in wells
  - — to provide additional groundwater level data
  - — for comparison with river stage elevation data

- Investigate the regional hydrogeology
  - — collect water level data in Bellefont Pond
  - — collect water level data in Roger Williams Park

- Investigate the impact of the bulkhead
  - — install clustered wells and piezometers near bulkhead to define impact of groundwater flow patterns

- Correlate downhole geophysical logging
  - — with hydraulic conductivity data
  - — to identify highly permeable zones with potential for contaminant migration pathways

- Conduct constant rate discharge pump tests
  - — in two recovery wells that will be installed near the bulkhead
  - — to determine the impact that pumping has on the river and
  - — to determine the impact of the bulkhead

Phase II Physical Characterization

Hydrological Investigation

Summary of Phase I Results

- Water discharge and stage measurements were used to generate working rating curves. The magnitude of discharge and the shape of the rating curves resemble USGS data for the Cranston gauge.
- Suspended sediment discharge increases with water discharge, but river water was transparent at very high flow rates.
- Riverbed sediments range from silt to gravel; calculations for the observed flows indicate that only silt or smaller-sized particles can be mobilized under these conditions.
- Groundwater discharge along the facility reach cannot be measured using stream discharge monitoring.

Phase I Data Gaps/Phase II Data Needs

- The Phase I sample locations selected were biased and results may not be generalizeable
- Effects of grain size will be isolated
- Additional sediment testing will be done to evaluate corrective measures
- Direct investigation of the riverbed will be done

Strategy for Phase II

- *Devise a stratified random sampling plan* to ensure generalizeability of results
- *Sample sediments* to isolate grain size effects and evaluate options for corrective measures
- *Additional discharge estimation* may be desired
- *Videotape riverbed* to investigate it directly

Activities Proposed for Phase II

- Devise a stratified random sampling plan
  — that allows for adjustments if difficulties occur in sampling at any particular location

- Sample sediments
  — in two rounds
  — sample fine- and coarse-grained sediment at same sampling locations
  — collect sediments for additional testing, as needed

- Additional discharge estimation
  — can be made using USGS Cranston gauge discharge records

- Videotape riverbed
  — using divers
  — who systematically follow a measured grid

Phase II Release Characterization

Production Area

SWMU-2 — 6000-Gallon Hazardous Waste Storage Tank

Summary of Phase I Results

- Few analytes of concern were detected in the soil samples from borings.
- Few analytes of concern were detected in the groundwater samples from a shallow well.
- Few analytes of concern were detected in the groundwater samples from a deep well.

Phase I Data Gaps/Phase II Data Needs

(none identified)

Strategy for Phase II

- *Risk assessment* of SWMU-2 to determine if Closure is appropriate

Activities Proposed for Phase II

- Risk assessment
  - — Closure, if appropriate based on risk assessment results
  - — Conduct additional delineation, if needed

Phase II Release Characterization

Production Area

SWMU-3 — 7500-Gallon, 90-Day Storage Tank

Summary of Phase I Results

- Groundwater samples from a shallow well contained ethylbenzene, toluene, and xylenes.
- Groundwater samples from a deep well contained ethylbenzene, toluene, and xylenes.
- Subsurface soil samples contained ethylbenzene, toluene, and xylenes.

Phase I Data Gaps/Phase II Data Needs

- Horizontal and vertical extent of soil contamination in the unsaturated zone around SWMU-3 will be delineated
- The extent of groundwater contamination near SWMU-3 will be delineated

Strategy for Phase II

- *Advance pilot borings* to delineate soil contamination in the unsaturated zone horizontally and vertically
- *Field-screen soil samples* from pilot borings
- *Analyze subsurface soil samples* based on field-screening results
- *Sample downgradient wells* to delineate the extent of groundwater contamination in the overburden aquifer

Activities Proposed for Phase II

- Advance pilot borings
  - — two borings
  - — downgradient of SWMU-3
- Field-screen soil samples
  - — using headspace analysis (HNu or OVA)
- Analyze subsurface soil samples
  - — select samples based on headspace readings
  - — submit samples for laboratory analysis
- Sample downgradient wells
  - — wells MW-13D and RC-1
  - — submit samples for laboratory analysis

Phase II Release Characterization

Production Area

SWMU-7 — Chlorosulfonic Acid Release Area

Summary of Phase I Results

- Groundwater samples from shallow wells contained ethylbenzene, toluene, and xylenes.
- Groundwater samples from deep wells contained ethylbenzene, toluene, and xylenes.
- Groundwater samples from a downgradient shallow well (MW-13S) contained the same compounds but at lower concentrations.
- Subsurface soil samples contained ethylbenzene, toluene, and xylenes.

Phase I Data Gaps/Phase II Data Needs

- Horizontal and vertical extent of soil contamination in the unsaturated zone around SWMU-7 will be delineated
- The extent of groundwater contamination near SWMU-7 will be delineated

Strategy for Phase II

- *Advance pilot borings* to delineate soil contamination in the unsaturated zone horizontally and vertically
- *Field-screen soil samples* from pilot borings
- *Analyze subsurface soil samples* based on field-screening results
- *Sample downgradient wells* to delineate the extent of groundwater contamination in the overburden aquifer

Activities Proposed for Phase II

- Advance pilot borings
  - — two borings
  - — downgradient of SWMU-7
- Field-screen soil samples
  - — using headspace analysis (HNu or OVA)
- Analyze subsurface soil samples
  - — select samples based on headspace readings
  - — submit samples for laboratory analysis
- Sample downgradient wells
  - — wells MW-13D and RC-1
  - — submit samples for laboratory analysis

Phase II Release Characterization

Production Area

SWMU-8 — Prussian Blue Release Area

Summary of Phase I Results

- Groundwater samples from a downgradient shallow well (MW-13S) contained benzene, toluene, xylenes, and 1,1-dichloroethane.
- Groundwater samples from a down/crossgradient shallow well (MW-3S) contained similar compounds but at lower concentrations.
- Subsurface soil samples contained ethylbenzene, toluene, and xylenes.

Phase I Data Gaps/Phase II Data Needs

- Horizontal and vertical extent of soil contamination in the unsaturated zone around SWMU-8 will be delineated
- The vertical extent of groundwater contamination at SWMU-8 will be delineated
- The extent of groundwater contamination downgradient of SWMU-8 will be delineated

Strategy for Phase II

- *Advance pilot borings* to delineate soil contamination in the unsaturated zone horizontally and vertically
- *Field-screen soil samples* from pilot borings
- *Analyze subsurface soil samples* based on field-screening results
- *Install a deep monitoring well* to delineate the extent of groundwater contamination in the deep overburden aquifer at SWMU-8
- *Sample recovery and monitoring wells* to delineate the extent of contamination downgradient of SWMU-8

Activities Proposed for Phase II

- Advance pilot borings
  - — two borings
  - — downgradient of SWMU-8
- Field-screen soil samples
  - — using headspace analysis (HNu or OVA)
- Analyze subsurface soil samples
  - — select samples based on headspace readings
  - — submit samples for laboratory analysis

- Install a deep monitoring well: see activities proposed for SWMU-7

- Sample recovery and monitoring wells
  — recovery well RC-1
  — monitoring well MW-13D
  — submit samples from RC-1 and MW-13D for laboratory analysis

Phase II Release Characterization

Production Area

SWMU-11 — Toluene Release Area

Summary of Phase I Results

- Groundwater samples from a shallow well contained chlorobenzene, ethylbenzene, toluene, xylenes, and 1,1,1-trichloroethane.
- Groundwater samples from a crossgradient shallow well contained similar compounds but at lower concentrations.
- Soil samples from borings contained similar compounds.

Phase I Data Gaps/Phase II Data Needs

- Horizontal and vertical extent of soil contamination in the unsaturated zone around SWMU-11 will be delineated
- The vertical extent of groundwater contamination at SWMU-11 will be delineated
- The extent of groundwater contamination downgradient of SWMU-11 will be delineated

Strategy for Phase II

- *Advance pilot borings* to delineate soil contamination in the unsaturated zone horizontally and vertically
- *Field-screen soil samples* from pilot borings
- *Analyze subsurface soil samples* based on field-screening results
- *Install a shallow monitoring well* to delineate the horizontal extent of contamination
- *Install deep monitoring wells* to delineate the extent of groundwater contamination in the deep overburden aquifer at SWMU-11
- *Sample recovery and monitoring wells* to delineate more completely the extent of contamination downgradient of SWMU-11

Activities Proposed for Phase II

- Advance pilot borings
  - — four borings
  - — downgradient of SWMU-11
- Field-screen soil samples
  - — using headspace analysis (HNu or OVA)
- Analyze subsurface soil samples
  - — select samples based on headspace readings
  - — submit samples for laboratory analysis

- Install a shallow monitoring well
  - — well MW-21S
  - — in Mill Street crossgradient of SWMU-11
  - — to delineate horizontal extent of contamination in the aquifer

- Install a deep monitoring well
  - — well MW-14D
  - — adjacent to MW-14S
  - — to delineate vertical extent of contamination in the aquifer beneath SWMU-11

- Install a second deep monitoring well
  - — well MW-4D
  - — adjacent to MW-4S
  - — to delineate vertical extent of contamination in the aquifer

- Sample recovery and monitoring wells
  - — recovery well RC-2
  - — monitoring wells MW-21S, MW-14D, and MW-4D
  - — submit samples for laboratory analysis

Phase II Release Characterization

Production Area

AOC-13 — Process Building Area

Summary of Phase I Results

- Groundwater samples contained analytes of concern (particularly chlorobenzene).
- Surficial soil samples contained analytes of concern (particularly PCBs).
- Subsurface soil samples contained analytes of concern.

Phase I Data Gaps/Phase II Data Needs

- Horizontal and vertical extent of soil contamination in the unsaturated zone around AOC-13 will be delineated
- The quality of groundwater entering AOC-13 will be evaluated
- The extent of groundwater contamination at AOC-13 will be delineated
- The extent of groundwater contamination at the bulkhead will be delineated
- The extent of river contamination by groundwater discharge from AOC-13 will be delineated

Strategy for Phase II

- *Advance and sample borings in the unsaturated zone* to delineate PCB contamination horizontally and vertically
- *Install a shallow monitoring well* upgradient of AOC-13 to monitor the quality of groundwater entering the area
- *Install shallow monitoring wells* to delineate the horizontal extent of contamination
- *Install a deep monitoring well* to delineate the vertical extent of groundwater contamination in the deep overburden aquifer near the bulkhead
- *Sample recovery wells* to delineate the horizontal and vertical extent of contamination near the bulkhead
- *Install shallow monitoring wells in the river* to delineate the extent of contamination by groundwater discharge from AOC-13
- *Install deep monitoring wells in the river* to delineate the extent of contamination in aquifer beneath the river by groundwater discharge from AOC-13
- *Sample monitoring wells* to delineate more completely the extent of contamination upgradient of, in, and around AOC-13 as well as in the river

Activities Proposed for Phase II

- Advance and sample borings in the unsaturated zone
  - — seventeen borings (including pilot holes for new wells)
  - — sample soils
  - — analyze soil samples for PCBs

- Install a shallow monitoring well
  - — upgradient (north) of AOC-13
  - — to monitor quality of groundwater entering AOC-13

- Install shallow monitoring wells
  - — 2 shallow wells
  - — to delineate horizontal extent of contamination in the aquifer

- Install a deep monitoring well
  - — adjacent to MW-2S (and adjacent to the bulkhead)
  - — to delineate vertical extent of contamination in the aquifer near the bulkhead

- Sample recovery wells
  - — recovery wells RC-1 and RC-2
  - — near the bulkhead
  - — and delineate extent of contamination in the aquifer near the bulkhead

- Install shallow monitoring wells in the river
  - — if permitted
  - — 3 shallow wells
  - — to delineate extent of contamination by groundwater discharge from AOC-13

- Install deep monitoring wells in the river
  - — if permitted
  - — 3 deep wells
  - — to delineate vertical extent of contamination in aquifer beneath the river

- Sample monitoring wells
  - — 3 shallow wells (one upgradient)
  - — 1 deep well (adjacent to bulkhead)
  - — 3 shallow wells (in river)
  - — 3 deep wells (in river)
  - — submit samples for laboratory analysis

Phase II Release Characterization

Production Area

AAOI-15 — Laboratory Building Waste Water Sump

Summary of Phase I Results

- Groundwater samples from a shallow well contained toluene.
- Few other analytes of concern were detected.

Phase I Data Gaps/Phase II Data Needs

(none identified)

Strategy for Phase II

- *Risk assessment* of AAOI-15 to determine if Closure is appropriate

Activities Proposed for Phase II

- Risk assessment
  - — Closure, if appropriate based on risk assessment results
  - — Conduct additional delineation, if needed

Phase II Release Characterization

Waste Water Treatment Area

SWMU-10 — Waste Water Pipeline Break – Waste Water Treatment Area

Summary of Phase I Results

- Few analytes of concern were detected in the soil samples.
- Few analytes of concern were detected in the groundwater samples.
- Few analytes of concern were detected in the surface water samples from the pond.
- Few analytes of concern were detected in the sediment samples from the pond.

Phase I Data Gaps/Phase II Data Needs

(none identified)

Strategy for Phase II

- *Risk assessment* of SWMU-10 to determine if Closure is appropriate

Activities Proposed for Phase II

- Risk assessment
  - — Closure, if appropriate based on risk assessment results
  - — Conduct additional delineation, if needed

Phase II Release Characterization

Waste Water Treatment Area

SWMU-12 — Waste Water Treatment Plant

Summary of Phase I Results

- Surficial soil samples contained primarily organic analytes of concern.
- Groundwater samples from a shallow well contained analytes of concern.

Phase I Data Gaps/Phase II Data Needs

- Horizontal and vertical extent of soil contamination will be delineated
- The extent of groundwater contamination in the overburden aquifer will be delineated

Strategy for Phase II

- *Conduct a soil gas survey* to delineate soil contamination horizontally
- *Advance borings* to sample soils and confirm the extent of soil contamination
- *Use a hydropunch* to delineate groundwater contamination horizontally
- *Install a shallow monitoring well* downgradient from SWMU-12 to delineate groundwater contamination in the overburden aquifer

Activities Proposed for Phase II

- Conduct a soil gas survey
  - — at a minimum of 25 sampling locations
  - — to field-screen soil
  - — by analyzing for total concentrations of volatile organic compounds
- Advance borings
  - — sample subsurface soils at 3 locations (minimum)
  - — submit samples for laboratory analysis
- Use a hydropunch
  - — at a minimum of 3 sampling locations
  - — to delineate the horizontal extent of groundwater contamination
- Install a shallow monitoring well
  - — at least one well (at a minimum)
  - — downgradient of SWMU-12
  - — submit groundwater samples for laboratory analysis
  - — to delineate extent of contamination in the shallow overburden aquifer

Phase II Release Characterization

Warwick Area

SWMU-5 — River Sediment Storage Area

Summary of Phase I Results

- Surficial soil samples contained chlorobenzene.
- Groundwater sample from a shallow well (MW-11S) contained chlorobenzene.
- Few other analytes of concern were detected.

Phase I Data Gaps/Phase II Data Needs

- Horizontal and vertical extent of soil contamination will be delineated
- The extent of groundwater contamination in the overburden aquifer will be delineated

Strategy for Phase II

- *Conduct a soil gas survey* to delineate soil contamination horizontally
- *Advance borings* to sample soils and confirm the extent of soil contamination
- *Use a hydropunch* to delineate groundwater contamination horizontally
- *Install a shallow monitoring well* downgradient from SWMU-5 to delineate horizontal groundwater contamination in the overburden aquifer
- *Install a deep monitoring well* downgradient from SWMU-5 to delineate vertical groundwater contamination in the overburden aquifer

Activities Proposed for Phase II

- Conduct a soil gas survey
  - — at a minimum of 25 sampling locations
  - — to field-screen soil
  - — by analyzing for total concentrations of volatile organic compounds
- Advance borings
  - — sample subsurface soils at 3 locations (minimum)
  - — submit samples for laboratory analysis
- Use a hydropunch
  - — at a minimum of 3 sampling locations
  - — to delineate the horizontal extent of groundwater contamination
- Install a shallow monitoring well
  - — at least one well (at a minimum)
  - — downgradient of SWMU-5
  - — submit groundwater samples for laboratory analysis
  - — to delineate extent of contamination in the shallow overburden aquifer

- Install a deep monitoring well
  - — adjacent to MW-11S
  - — submit groundwater samples for laboratory analysis
  - — to delineate vertical extent of contamination in the aquifer beneath SWMU-5

Phase II Release Characterization

Warwick Area

SWMU-6 — Zinc Oxide/Soil Storage Pile

Summary of Phase I Results

- Surficial soil samples contained zinc.
- Few other analytes of concern were detected in the surficial soil samples.

Phase I Data Gaps/Phase II Data Needs

(none identified)

Strategy for Phase II

- *Risk assessment* of SWMU-6 to determine if Closure is appropriate

Activities Proposed for Phase II

- Risk assessment
  - — Closure, if appropriate based on risk assessment results
  - — Conduct additional delineation, if needed

Phase II Release Characterization

Warwick Area

SWMU-9 — Waste Water Pipeline Break – Warwick Area

Summary of Phase I Results

- Few analytes of concern were detected in the surficial soil samples.

Phase I Data Gaps/Phase II Data Needs

(none identified)

Strategy for Phase II

- *Risk assessment* of SWMU-9 to determine if Closure is appropriate

Activities Proposed for Phase II

- Risk assessment
  - — Closure, if appropriate based on risk assessment results
  - — Conduct additional delineation, if needed

Phase II Release Characterization

Warwick Area

AAOI-16 — Maintenance Department Cleaning Area

Summary of Phase I Results

- Few analytes of concern were detected in the subsurface soil sample.
- Groundwater samples from the shallow overburden aquifer contained 1,1,1-trichloroethane (TCA).
- Few analytes of concern were detected in groundwater samples from the deep overburden aquifer.

Phase I Data Gaps/Phase II Data Needs

- The extent of groundwater contamination in the shallow overburden aquifer will be delineated

Strategy for Phase II

- *Conduct a soil gas survey* to delineate soil contamination horizontally
- *Advance borings* to sample soils and confirm the extent of soil contamination
- *Use a hydropunch* to delineate groundwater contamination horizontally
- *Install a shallow monitoring well* downgradient from AAOI-16 to delineate groundwater contamination in the overburden aquifer

Activities Proposed for Phase II

- Conduct a soil gas survey
  - — at a minimum of 12 sampling locations
  - — to field-screen soil
  - — by analyzing for total concentrations of volatile organic compounds
- Advance borings
  - — sample subsurface soils at 2 locations (minimum)
  - — submit samples for laboratory analysis
- Use a hydropunch
  - — at a minimum of 3 sampling locations
  - — to delineate the horizontal extent of groundwater contamination
- Install a shallow monitoring well
  - — at least one (at a minimum)
  - — downgradient of AAOI-16
  - — submit groundwater samples for laboratory analysis
  - — to delineate extent of contamination in the shallow overburden aquifer

Phase II Release Characterization

Pawtuxet River

Summary of Phase I Results

- Surface water chemistry was similar along all reaches of the river; surface water samples contained low levels of VOCs, phthalates, pesticides, lead, nickel, silver, and zinc.
- All sediment samples contained analytes of concern; the highest levels were in samples from the facility reach. The analytes detected include VOCs, phthalates, PAHs, phenols, fingerprint compounds, chlorinated benzenes, PCBs, dioxins/furans, pesticides, herbicides, and heavy metals.
- Poor survival rates of midge larvae were observed in facility reach sediment samples and in the far downstream sample. Lowered survival rates of daphnids were observed in the pore water of some facility reach sediment samples

Phase I Data Gaps/Phase II Data Needs

- The Phase I sample locations selected were biased and results may not be generalizeable
- Effects of grain size will be isolated
- Additional sediment testing will be done to evaluate corrective measures
- Vertical variation of contaminants and other analytes/parameters will be measured in both surface water and sediment
- Horizontal variation of contaminants and other analytes/parameters will be measured in sediments
- Temporal changes in surface water chemistry will be evaluated

Strategy for Phase II

- *Devise a stratified random sampling plan* to ensure generalizeability of results
- *Sample sediments* to isolate grain size effects, evaluate options for corrective measures, and delineate vertical and horizontal extent of contamination
- *Sample surface water* to delineate vertical changes of contaminants and other analytes/parameters
- *Sample surface water at one location repeatedly* to document temporal changes

Activities Proposed for Phase II

- Devise a stratified random sampling plan
  — that allows for adjustments if difficulties occur in sampling at any particular location

- Sample sediments
  - — in two rounds
  - — sample fine- and coarse-grained sediment at same sampling locations
  - — collect sediments for additional testing
- Sample surface water
  - — in two rounds
- Sample surface water at one location repeatedly
  - — frequently
  - — for a period of time
  - — to document temporal changes

Phase II Off-Site Investigation

Background Locations

Summary of Phase I Results

- Groundwater samples from the shallow upgradient wells contained PAHs, pesticides, arsenic, chromium, manganese, and iron.
- Groundwater samples from the off-site rock well contained pesticides, manganese, and iron.
- Few analytes of concern were detected in soil samples from the off-site background locations.

Phase I Data Gaps/Phase II Data Needs

- Background chemistry of groundwater entering the Warwick Area from off-site will be determined
- Resampling background soil sampling locations will be done if necessary to satisfy risk assessment needs

Strategy for Phase II

- *Install monitoring wells* upgradient of the Warwick Area to monitor the quality of the groundwater entering the shallow overburden aquifer in the Warwick Area from off-site
- *Resample background soil sampling locations*, if needed

Activities Proposed for Phase II

- Install monitoring wells
  - — upgradient (south) of Warwick Area
  - — sample groundwater in the shallow overburden aquifer
  - — to monitor quality of groundwater entering the Warwick Area and
  - — to characterize the background water quality more completely
- Resample background soil sampling locations
  - — if needed based on Phase I results

Phase II Off-Site Investigation

Other Locations

Summary of Phase I Results

(no other off-site locations were sampled in Round 1; no results are available at this time)

Phase I Data Gaps/Phase II Data Needs

- Sampling to confirm the Phase I results will be conducted
- Additional sampling will be done, if needed

Strategy for Phase II

- *Resample the other off-site locations* to confirm the results from the Phase I samples
- *Propose additional sampling* of off-site locations (if appropriate)

Activities Proposed for Phase II

- Resample the other off-site locations
  — 14 locations
- Propose additional sampling
  — if appropriate
  — based on results from two rounds of sampling

ATTACHMENT A

Other Phase II Work Activities Proposed

PHASE II PHERE

Groundwater Modeling

Summary of Phase I Results

- Geological, hydrological, and hydrogeological data were assembled into a conceptual site model.
- Analytical data indicate the presence of contaminants in the soil-groundwater-river system.

Phase I Data Gaps/Phase II Data Needs

- Some additional sampling and analyses are needed to verify the conceptual site model. These data gaps are delineated elsewhere in this proposal under hydrology and hydrogeology.

Strategy for Phase II

- Collect data needed to verify conceptual site model.
- Use modeling techniques in support of the PHERE.
- Provide risk information on various alternative corrective measures.

Activities Proposed for Phase II

- Groundwater Modeling
  - -- Construct a numerical model to predict directions and velocities of groundwater flow and to predict migration and transformation of contaminants. Verify numerical model to the extent permitted by available data.
- Exposure Point Concentrations
  - -- Predict concentrations of contaminants at receptor locations under various scenarios associated with different patterns of land use and different candidate corrective measures.
- Assess possible risks due to exposure to contaminants.

PHASE II PHERE

Aquatic and Riparian Survey

Summary of Phase I Results

- Contaminants were found in soil and groundwater at the site and in river sediment near the site. Some of the river sediments were toxic.

Phase I Data Gaps/Phase II Data Needs

- Survey of biological communities is required to determine impact of human activities at the site.

Strategy for Phase II

- Determine environmental populations at risk.
- Determine applicability of bioassay test results to local species.
- Provide risk information on various alternative corrective measures.

Activities Proposed for Phase II

- Survey the mammalian, avian, aquatic, and benthic communities near the site, including the upstream and downstream areas. Construct food web relationships.
- Identify insect populations similar to *Chironomus tentans*, the insect larva found to be sensitive in the bioassays.

PHASE II PHERE

Bioassay of Sediment Spiked with Methyl Parathion

Summary of Phase I Results

- Methyl parathion, an insecticide, was present in two sediment samples which were toxic to the insect, *C. tentans*. Other chemicals were present in these samples, but not at concentrations consistent with the level of toxicity observed.

Phase I Data Gaps/Phase II Data Needs

- The sensitivity of *C. tentans* to methyl parathion under the conditions of the bioassay is not known.

Strategy for Phase II

- Determine if methyl parathion might have caused toxicity in sediments.

Activities Proposed for Phase II

- Search the scientific literature for information on the toxicity of *C. tentans* or similar species to methyl parathion.

- Conduct bioassays with *C. tentans* to establish a concentration-lethality relationship, using reference sediment samples spiked with known concentrations of methyl parathion.